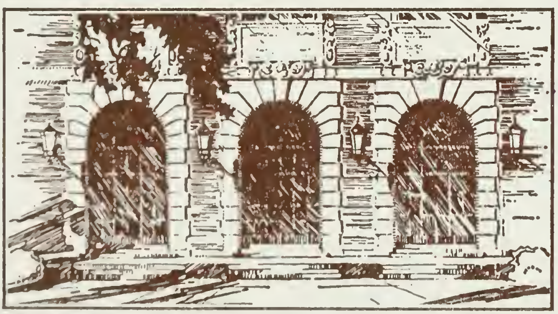

IVERSITY OF ILLINOIS **BULLETIN**

180-DEGREE TURN
experiment

VERSITY OF ILLINOIS INSTITUTE OF AVIATION URBANA

AERONAUTICS BULLETIN NUMBER **11**

UNIVERSITY OF ILLINOIS INSTITUTE OF AVIATION

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180-DEGREE TURN
experiment

by

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Foreword

The Aircraft Owners and Pilots Association Foundation, Inc., has long been concerned with methods for reducing the number of civil aviation light aircraft accidents caused by bad weather conditions. The Institute of Aviation has had a continuing interest and has gained valuable experience in improved pilot training and in the problems of aircraft stability. It was therefore logical that the two groups should join forces to devise a curriculum which would train a noninstrument pilot to "get out of" weather conditions into which he had flown inadvertently.

The AOPA Foundation, Inc., provided the funds for the experiment, and the Institute then developed a curriculum which would train a noninstrument pilot to retain control of his aircraft sufficiently well under instrument weather conditions to enable him to fly back to noninstrument conditions. The suggested curriculum is a "fly out" not a "fly through" procedure. Since the curriculum accomplished its proposed purpose, it is presented in detail in the second part of the text, together with comments and suggestions to be used in teaching the procedure.

Both the Institute and the AOPA Foundation, Inc., believe that they are rendering a public service to personal flying by making this procedure available. The Institute would like to have amassed considerably more data and to have spent more time on the project, but the results appeared so conclusive that no purpose would have been served in the interests of aviation safety by a further withholding of results.

The authors gratefully acknowledge the assistance, criticism, and advice of the following people: Captain Paul A. Soderlind, Northwest Orient Airlines; Dr. A. C. Williams, University of Illinois; Clifford P. Marye, Flight Instructor, University of Illinois; Dr. August Raspet, Mississippi State College; Francis B. Schaber, Shop Foreman, University of Illinois; John P. Gaty, Vice-President, Beech Aircraft Corporation; Bert A. Shields, Civil Aeronautics Board; and Kenneth R. Aldrich and Carl W. Clifford, Civil Aeronautics Administration.

The above persons have assisted in varying degrees. This acknowledgment does not necessarily imply endorsement by them of the experiment or its results.

Thanks should also be extended to the subjects who participated in these case studies and to the staff of the flight and the aircraft maintenance departments of the Institute of Aviation for their generous donations of time and for their patience during the project.

In this monograph, as in all publications of the Institute, the authors have had complete freedom to express their opinions, with the understanding that they will assume sole responsibility therefor.

June, 1954 LESLIE A. BRYAN, *Director*

The Approach to the Problem . . . .

THE PROBLEM

The instructions from the AOPA Foundation were, "Devise simple, practical curriculum for special training program intended only to teach pilot to keep plane upright if caught on instruments, make good enough 180-degree turn to get back to VFR weather, or get down through cloud deck." These instructions were interpreted to mean that the final product should be: (1) simple, (2) universally applicable to all light single-engine airplanes, and (3) inexpensive and practical in terms of time and money.

PRELIMINARY INVESTIGATION

A thorough search was made in current periodicals, books, and syllabi for articles on simplified instrument flying technique. Numerous consultations were held with expert instrument pilots, including the Institute of Aviation staff, airline pilots, and instrument pilots on the staff of the Aviation Psychology Laboratory at the University of Illinois. The resulting decision was to investigate a technique, not completely new, but well described in an article by Paul A. Soderlind, entitled "Instrument Lifesaver for the Contact Pilot."

Numerous flights were made in five different types of light aircraft, during which the proposed technique was tested with entries made from all attitudes and conditions of flight. Several weeks of flight testing, staff consultations, and pretesting of three noninstrument pilots resulted in a revised technique which seemed acceptable within the AOPA Foundation directive. The system finally evolved differs in some respects from that suggested by Soderlind, but the basic principles are the same.

A noninstrument pilot is an individual who does not hold a CAA instrument rating or its equivalent. Instrument weather is that atmospheric condition in which the pilot has no visual points of reference outside the aircraft. Most noninstrument pilots can be placed in one of the three following categories: (1) the noninstrument pilot who knows he could not fly instruments and takes every precaution to avoid instrument weather; (2) the noninstrument pilot who "knows" he could not fly instruments, takes every precaution to avoid instrument weather, but believes his knowledge and experience would enable him, if caught, to fly out of the instrument weather; (3) the noninstrument pilot who believes, primarily through ignorance of the problems involved, he could fly through instrument weather.

The syllabus evolved for teaching the technique is aimed directly at these three types of noninstrument pilots.

Incipient Dangerous Flight Conditions

CONTRIBUTORY CONSIDERATIONS

This study is concerned with serious, near-fatal, and fatal accidents which occur because pilots, untrained in instrument flying, attempt to fly under actual instrument conditions.

Such accidents (1) occur with the greatest frequency in single-engine airplanes of less than 5,000 pounds gross weight, (2) happen in airplanes which are equipped with either partial or full instrument panels, (3) occur with the greatest frequency to noninstrument-rated pilots, (4) happen most often to pilots who have had no previous experience under either actual or simulated instrument conditions, and (5) occur in marginal or sub-marginal weather conditions.

All authorities agree that nonprofessional pilots, untrained in instrument flying techniques, place too much emphasis on instrument-flying equipment and too little emphasis on proper training in the use of instruments. Experts are at a complete loss to explain the enigma of a businessman pilot who invests several thousands of dollars in an airplane with a full instrument panel, radio equipment, and even an auto-pilot, but who is apparently unwilling to invest additional funds or the time to obtain instrument experience which would enable him to make the safest and most efficient use of his airplane.

A majority of the experts expressed the belief that all student pilots should be thoroughly acquainted with the problems of instrument flying through an actual experience under simulated instrument flight conditions, similar to Period 1 in "The 180-Degree Turn Syllabus," *prior to* authorization for their first solo cross-country flight.[1]

It seems true also that a large majority of the nonprofessional pilots, untrained in instrument flying, entertain a basic misconception about the nature of instrument flying. This misconception centers around the idea that instrument flying can be learned through a series of flights under progressively lower visibilities, where the technique employed is gradually modified from that used under CAVU conditions to that employed under instrument conditions. In addition, it was felt that many of these pilots mistakenly believe that the techniques involved in visual night flying were closely related to instrument flying. However, the difference between visual flying and instrument flying is neither the degree of visibility nor the number of reference points available to the pilot; instrument flying is denoted by the reference points used for controlling the attitude of the airplane which are located inside not outside the airplane. It is not how much the pilot sees, but where he sees it.[2]

THE NATURE OF ACCIDENTS

The type of accidents under consideration usually take one of two forms, either the so-called "graveyard spiral" or the "roller coaster."

The "graveyard spiral" is the most prevalent, and it is abetted by the lack of positive spiral stability in present-day aircraft. The following series of events are involved: (1) shortly after entering instrument conditions the airplane starts to turn,[3] (2) the pilot fails to note the turn or, if he does note it, fails to correct usually because of vertigo, (3) the bank increases causing the nose to cant downward which results in an increase in airspeed, (4) the pilot recognizes the increased airspeed and applies corrective measures in the form of increased back-pressure on the yoke

[1] It is interesting to note that the twenty subjects in this case study were unanimous on this point after they had completed Period 1. This procedure has been standard practice at the University of Illinois for a number of years with beginning students.

[2] An experiment conducted by the Aviation Psychology Laboratory at the University of Illinois indicated that a relatively inexperienced pilot can do a reasonably safe job of piloting an airplane with only an extremely limited view outside the cockpit.

[3] This may be caused by any number of events — the pilot, a gust, imperfect lateral balance, etc.

or stick, (5) the increased back-pressure tightens the turn, the nose cants downward, the airspeed increases, and more back-pressure is applied in an effort to slow up the airspeed.

To an observer riding along, it appears that the pilot rolls gently into an increasingly steeper bank and allows the degree of dive to increase simultaneously. Under these conditions a very short time is required for the airplane to go from normal flight into a diving spiral, a 60- to 70-degree bank, and the red-line airspeed; the cleaner the airplane, the less time required for this to happen.

The second variety, appropriately called the "roller coaster," occurs when the pilot fixes his attention on the airspeed indicator and/or the altimeter. The pilot is inclined to rely on these two instruments in an unfamiliar situation since they are the instruments most frequently used under visual conditions. However, the pilot fails — or is unaware of the necessity — to allow for momentum lag. In an effort to make the indicators show the desired reading, he puts the airplane through a series of increasingly violent climbs and dives. Unfortunately, the "lagging" instruments give the impression that the airplane is at the top of a climb when it is actually in a diving attitude, or vice versa. The final result is usually a structural failure due to excessive G loads.

THE CRITERIA

For the purpose of this study a Beechcraft Bonanza C-35 was selected. On the basis of preliminary testing it was decided that for the purpose of this study an incipient dangerous flight condition and/or attitude had been reached when the subject pilot allowed any one or any combination of the following situations to develop: (1) a stall, either normal or accelerated; (2) a bank in excess of a medium bank (45 degrees); (3) a speed in excess of normal fast cruise; (4) obvious and prolonged loss of either altitude or directional orientation.

Normal equipment on the aircraft used enabled the instructor to take absolute measurements of the first three situations, and it was agreed that the fourth must necessarily be an arbitrary decision based on the circumstances existing at the time.

Subjects Selected for the Case Studies

PRETEST SUBJECTS

Three private pilots, none of whom had had previous instrument flight experience under either simulated or actual conditions, were selected as pretest subjects. These subjects were put through an experimental syllabus based on the experience gained from the preliminary flights. The results thus obtained were encouraging and the test syllabus was modified in accordance with the findings on the pretest subjects. Primary modifications were (1) a standardized recording sheet, (2) the addition of the present flight number 1, and (3) the addition of a "free trial" experience in the final period.

Pretest subjects are not included in the tables showing the results of the case studies.

BASES OF SELECTION

The same basic criterion used in selecting the airplane, that of testing the technique under the most adverse circumstances possible, was adopted in selecting the subjects.

The bases of selection for the volunteer case study subjects were that they should (1) be representative as to chronological age — the group selected ranged in age from 19 to 60 years, (2) have had no previous instrument experience under either simulated or actual conditions, (3) have had a minimum of experience in the Beechcraft Bonanza, and (4) be as representative as possible with respect to actual logged flight time.

Twenty subjects were selected on the basis of the above criteria. Table 1 shows the age, pilot certificate, airplanes flown, and logged flight experience of the subjects used in the case study.

The Airplane and Equipment

CHOICE OF THE BEECHCRAFT BONANZA

The Beechcraft Bonanza C-35 was selected for use in these case studies upon the basis of the preliminary flight testing which indicated that the technique would be most difficult to accomplish in the Bonanza. The Bonanza was also considered representative of the most complex light single-engine airplane normally flown by the nonprofessional, noninstrument pilot. In addition, it was desirable to use an airplane with which the subject had had the least amount of experience. In short, the assumption was made that if the subjects, none of whom had soloed a Bonanza, could master the technique in this airplane, they could master it in any single-engine airplane under 3,000 pounds gross weight.

TABLE 1. FLIGHT EXPERIENCE

SUBJECT	AGE	CERTIFICATE	AIRPLANES FLOWN	DUAL	SOLO	CROSS-COUNTRY[4]	NIGHT[4]	INSTRU-MENT	TOTAL[5] TIME
#1	47	Private ASEL	Aeronca 7AC, Cessna 140, Cessna 170, Piper-Pacer, Tri-Pacer, Bonanza, Ercoupe	97.4	185.8	160.0	16.5	0	283.2
#2	19	Private ASEL	Aeronca 7AC, Aeronca 11AC, Cessna 140, Tri-Pacer, Fairchild PT-19	20.0	11.0	12.0	4.0	0	31.0
#3	19	Private ASEL	Aeronca 7AC, Cessna 140, Tri-Pacer	20.0	12.0	9.0	2.0	0	32.0
#4	23	Private ASEL	Piper J-3, Stinson 150, Vultee BT-13, Cessna 140, Luscombe, Taylorcraft, Boeing	40.0	110.0	25.0	2.0	0	150.0
#5	23	Private ASEL	Aeronca 7AC, Cessna 140, Tri-Pacer	28.0	10.0	11.0	2.0	0	38.0
#6	60	Private ASEL	Aeronca 7AC, Cessna 140, Tri-Pacer	40.0	130.0	75.0	30.0	0	170.0
#7	25	Private ASEL	Aeronca 7AC, Tri-Pacer	20.0	11.0	13.0	3.0	0	31.0
#8	33	Private ASEL	Aeronca 7AC, Cessna 140, Bonanza	40.4	154.9	77.3	12.4	0	195.3
#9	21	Private ASEL	Aeronca 7AC, Cessna 140, Cessna 170, Piper-Pacer, Piper J-3	22.7	14.1	13.0	3.0	0	36.8
#10	25	Private ASEL	Aeronca 7AC, Piper-Pacer	21.0	10.0	9.0	2.0	0	31.0
#11	32	Private ASEL	Piper J-3, Tri-Pacer, Piper Cruiser	20.0	150.0	0	0	0	170.0
#12	41	Student	Cessna 140, Piper J-3	20.0	25.0	7.0	0	0	45.0
#13	48	Private ASEL	Ercoupe, Stinson 150, Cessna 140	30.0	470.0	400.0	0	0	500.0
#14	20	Private ASEL	Aeronca 7AC, Cessna 140, Piper-Pacer	20.0	11.0	10.0	4.0	0	31.0
#15	24	Private ASEL	Aeronca 7AC, Stinson 150, Fairchild PT26	20.0	65.0	15.0	1.0	0	85.0
#16	55	Private ASEL	SEL from 45 to 260 HP, Pilot since 1918	400.0	925.0	600.0	0	0	1325.0
#17	47	Private ASEL	Aeronca 7AC, Cessna 140, Ercoupe	21.0	96.0	80.0	0	0	117.0
#18	44	Private ASEL	Aeronca 7AC, Cessna 140 & 170, Tri-Pacer	40.0	175.0	175.0	8.0	0	215.0
#19	46	Private ASEL	Aeronca: 7AC, 11AC, Cessna: 140, 170, PT-19, Piper: Pacer, Tri-Pacer, J-3, PA-11, Ercoupe	80.0	300.0	100.0	50.0	0	380.0
#20	53	Private ASEL	Aeronca 7AC, Cessna 140, Ercoupe	25.0	1600.0	1500.0	25.0	0	1625.0

[4] Cross-country, night, and instrument flight times are already included in the DUAL and/or SOLO figures.

[5] The range here ran from a 31-hour minimum to a 1625-hour maximum. It is possible to obtain a private license at the University of Illinois, under the approved school certificate, with a minimum of 30:18 hours.

EQUIPMENT IN THE AIRPLANE

In the experiment it was decided to use only those instruments and equipment specified in Civil Air Regulation 43.30 for visual flight rules, plus a turn indicator. Therefore in equipping a standard Beechcraft C-35 for these case studies, the artificial horizon, the directional gyro, and the rate-of-climb indicators were covered. Amber plexiglass covered the windshield and the side glasses. The subject pilot was equipped with nonpolarizing blue goggles to simulate instrument flight conditions. The amber-blue combination reduced the cockpit visibility to an undesirable degree, however, and it was necessary to install additional cabin lights — one focused on the compass and the second spotted on the instrument panel. Even with the additional lights, most subjects found it difficult to read the trim-tab indicator. As a consequence, the instructor carried a flashlight for spotting this indicator when it was necessary for the subject to read it. Before each flight, the instructor checked the blue goggles and the amber windshield for possible spots through which the subject might have outside visibility.

THE LOADING CONDITION

For the purposes of the case studies, the airplane was loaded in the most rearward allowable center of gravity (c.g.) condition.[6] The airplane was loaded to maximum gross weight, 2700 pounds, with one subject and one flight instructor occupying the front seats, a full load of fuel and oil, sandbags weighing 340 pounds in the rear seat, and a 50-pound sandbag in the baggage compartment. This gave a rearward c.g. of +84.16 aft of datum for take-off; the allowable limit was calculated as +84.4.

All flights were limited to a maximum of 80-minutes duration during which time, because of fuel consumed, the gross weight became 2620 pounds, and the calculated c.g. position was +84.4 aft of datum. The allowable c.g. limit for a gross weight of 2620 pounds was calculated as being +84.43 aft of datum.

Frequently a second flight instructor occupied the right rear seat. In this case, an amount of sand equal to the weight of the instructor was removed from the rear seat.

THE LANDING GEAR PROBLEM

In initial tests of the technique, the landing gear was not lowered until the speed had been reduced to that recommended by the airplane

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[6] The complete weight and balance form in this instance is reproduced in the appendix.

Handbook (not above 125 m.p.h.). This necessitated lowering the gear as one of the final steps, thereby losing the advantage of using extended gear to slow the airplane. It was subsequently learned that the Bonanza gear could be lowered, without danger, at cruising speed. This was done throughout the complete experiment.

FLAPS AND COWL FLAPS

During the preliminary testing of the technique and the pretest subject flights, it was found that full flaps on the Bonanza resulted in an extreme forward (nose-down) pitching moment. With full flaps and the airplane loaded in the rearward c.g. condition almost full nose-up trim tab was required to obtain the desired airspeed of 95 m.p.h.

The wide range of trim-tab travel required to compensate for full flaps resulted in a greater number of phugoid[7] oscillations with greater extremes in attitude at the top and bottom of the oscillation. When the oscillations had ceased there was no apparent improvement in the longitudinal stability of the airplane.

Because the use of flaps involved two undesirable effects — one more task for the pilot to perform and a greater number of and wider extremes in oscillations — it was decided to perform the entire project without using flaps.

Experiences with the Bonanza indicate that the use of flaps by noninstrument pilots, when encountering instrument weather conditions unexpectedly, is not to be recommended; such use of flaps complicates rather than simplifies the task of controlling the airplane.

The cowl flaps and carburetor heat on the Bonanza were omitted in planning the procedure, since opening and closing them further complicated matters for the subject. It was decided that undue heating and/or cooling, except under rare circumstances, would not be experienced to a degree which would result in a dangerous flight condition.

Analysis of the Technique

BASIC CONCEPTS OF THE TECHNIQUE

The noninstrument pilot encountering either actual or simulated instrument flight conditions for the first time usually overcontrols the

[7] Hereafter when oscillation is used it will refer to phugoid oscillation, i.e., a long period oscillation characteristic of the disturbed longitudinal motion of an airplane.

airplane. He is also likely to fix his attention on one instrument and ignore the others. Hence, the technique described below is intended to (1) utilize the inherent stability of the airplane as a partial solution to the complexity of the problem, (2) reduce the possibility of overcontrol, (3) minimize the control required to obtain the desired result, (4) limit the division of attention on the part of the pilot, (5) reduce the possibility of structural damage through excess speed and the potential attendant G loads, and (6) teach the pilot the "key" instruments upon which he should concentrate his attention.

THE TECHNIQUE

The technique is mechanical and requires a minimum of practice and skill. *We do not consider the use of the technique to be instrument flying in the usual sense.* For the twenty case studies reported, the steps were typed on a small card which was affixed to the instrument panel. Thus it could be read as a check-list by the pilot.

Immediately upon entering instrument weather the pilot must complete, in order, the following steps:

Center the Turn Needle. This is not listed as a specific step because it is a continuing task and requires more attention and skill than any of the steps. The needle should be centered and kept centered by alternating the attention between the progressive steps and the needle. Centering is done entirely with the rudder.

(1) *Hands Off.* This eliminates the possibility of overcontrolling the elevator and places reliance upon the inherent angle of attack (speed seeking or pitch) stability of the airplane. The highest speed obtained after the hands are removed will be that for which the airplane is trimmed, provided the airplane is not allowed to enter a spiral dive.

(2) *Lower the Gear.* This step is accomplished at cruising speed. The added drag will materially reduce the possibility of excessive speeds.[8]

(3) *Reduce Power.* Power should be reduced to a position somewhat above idling.

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[8] Mr. John P. Gaty, Vice-President and General Manager of Beech Aircraft, Inc., states, "We feel that it would be safe to extend the [Bonanza] landing gear as long as the airspeed indicator is in the green sector, which is up to 160 m.p.h. indicated. Probably in emergency conditions, it might be reasonable to extend the landing gear as long as the airspeed is in the yellow sector, which would top 202 m.p.h."

(4) *Set Trim Tab.* The trim tab is rolled to a predetermined and premarked position which will give the desired slow flight speed — in the case of the Bonanza, 95 m.p.h. — with the airplane loaded in the most rearward allowable c.g. position. The speed and the trim-tab setting required to obtain the speed is determined experimentally and under visual flight conditions.[9]

(5) *Adjust Prop Pitch and Power.* The prop pitch should be in the full high r.p.m. (low-pitch) position. The power (either tachometer or manifold pressure) should be set to a predetermined, premarked position. The power required is to be determined experimentally and under visual conditions after the trim-tab setting is found for the desired speed. When the airplane is trimmed for the slow speed (Bonanza, 95 m.p.h.) and the prop is in high r.p.m., the power is then adjusted to the amount required to maintain altitude exactly. In the Bonanza this is approximately 17 inches with the prop in high r.p.m.

The foregoing steps should be accomplished positively, without hesitation or waiting, and in the order listed. The completed steps will cause the airplane to go through a series of oscillations. The number of oscillations and the severity — extremes in longitudinal pitch — will be directly affected by the interval between steps. Once the steps are started they should be completed without pausing between steps. Pausing or delaying between steps will result in a variety of unusual attitudes, depending upon where the pause occurs. On the other hand, if the steps are completed without hesitation, the transition from cruising to slow flight will be accomplished with the minimum of oscillations.

(6) *Note Compass Heading.* The heading may or may not be the heading of original entry. However, the pilot should determine the reciprocal of the original heading which led him into the instrument weather.

(7) *Turn with Rudder.* The turn needle should be moved to a three-fourths standard rate turn position using the rudder only, and the pilot should concentrate on maintaining a constant rate of turn, i.e., keeping the needle as nearly on the three-fourths standard position as possible. The three-fourths standard rate turn is used rather than the standard rate because of the shal-

[9] A table of recommended speeds for various light single-engine airplanes is included on page 22. Any predetermined speed can be set up. The recommended speeds represent the authors' opinions as being the best, all things considered.

lower bank required and the fact that acceleration (change in rate of turn) is less likely.

(8) *Roll Out with Lead or Lag.* This refers to the "lead" or "lag" required to compensate for inherent compass errors including dip, northerly turning error, and acceleration error.

(9) *Center the Needle and Note the Heading.* If the desired heading appears after the compass settles down, the problem is one of keeping the needle centered until visual conditions reappear. If the desired heading is missed by more than 30 degrees, appropriate corrections should be made. If visual contact is not made within a few minutes, the next step should be started immediately.

(10) *Reduce Power.* The power should be reduced a predetermined amount to give a 400- to 500-f.p.m. rate of descent. This probably will mean a reduction of 5 to 6 inches of manifold pressure or 300 to 500 r.p.m. in the case of fixed-pitch propellers.[10]

Of the foregoing steps, psychologically the most difficult one to accomplish is the first, *Hands Off,* and in many respects it is the most important one. The step requiring the greatest degree of skill and practice is controlling the needle through rudder action. The most novel step to nonprofessional pilots is that of using the compass to indicate completion of a turn.

Case Study Procedure

GENERAL

The twenty subjects selected were given the course of instruction and the tests outlined in detail in the syllabus. In order to eliminate instructor differences, only one flight instructor was used for the twenty cases studied; occasionally, a second flight instructor occupied the right rear seat for purposes of observing or recording the performance of the subject.

Accurate records of flight time, simulated instrument time, and performances were kept by the instructor. The tracks were diagrammed wherever practical and/or applicable. The records on a representative case are reproduced on page 53.

It will be noted that the syllabus includes six periods, each of which consists of approximately 20 minutes of discussion and 40 minutes of

[10] If, in the exceptional case, it is desired to climb, increasing the manifold pressure 5 to 6 inches, or 300 to 500 r.p.m. in the case of fixed-pitch propellers, will accomplish the desired purpose.

flight. The first and last periods are devoted entirely to testing; the four intermediate periods are devoted to teaching.

The purpose of the first period was twofold — to acquire some indication of the subject's ability to control the airplane under simulated instrument conditions, against which his final flight performance could be measured, and to provide the student with a subjective appraisal of his own ability as an instrument pilot.

Standard altitude for beginning the first simulated instrument flight was 2500 feet above mean sea level (1750 feet actual). Higher altitudes were used during the first flights of the first five subjects; a change was made to the lower altitude because the potential disaster was more apparent to the subject if the ground was literally "staring him in the face" when he raised his goggles.

Nineteen subjects placed the airplane in a "graveyard spiral" on the first attempt to fly by instruments. The twentieth subject pulled the airplane into a whip-stall attitude. Minimum time to reach the incipient dangerous attitude was 20 seconds; maximum time was 8 minutes. These results reaffirm the generally accepted premise that the spiral instability of present-day light aircraft, together with the pilot's lack of instrument flight experience, is a major factor contributing to fatal accidents.

The flight instructor recovered from the "graveyard spiral" cases at the 185 m.p.h. indicated. This speed was selected because the airplane

TABLE II

Subject Number	Time Elapsed[11] in Seconds	Subject Number	Time Elapsed[11] in Seconds
1	170	11	180
2	190	12	40
3	61	13	124
4	150	14	60
5	243	15	20
6	364	16	181
7	20	17	65
8	480	18	58
9	210	19	360
10	180	20	420

The average time was 178 seconds or 2 seconds short of 3 minutes.

[11] This time is included in the subject's simulated instrument time shown in Table III.

was in a bank and dive sufficiently steep so that the airspeed reached 200 m.p.h. by the time recovery had been effected. The recovery from the whip-stall attitude was effected before the actual stall occurred. In all cases the subjects were instructed to remove the goggles before the instructor started the recovery, so that the subject could definitely observe the attitude of the airplane before the recovery was effected. The first attempt to control the airplane solely by reference to instruments proved a startling experience to all pilots tested regardless of the amount of previous flight experience under visual conditions.

Table II shows the time required by each subject to reach an incipient dangerous flight condition. The time shown is the total time from the point the goggles were placed over the subject's eyes to the moment he was instructed to remove the goggles and observe the dangerous attitude of the airplane.

THE INSTRUCTION PERIODS

Periods 2, 3, 4, and 5 in the syllabus are devoted entirely to teaching the technique. In general, the first five steps were introduced in Period 2, the second five steps in Period 3, and Periods 4 and 5 were devoted to practice.

Eighteen of the subjects were considered proficient at the end of Period 5 and were given the flight test described under Period 6. The two remaining subjects were given an extra period of practice (Period 5X) and were then given the test indicated in Period 6.

Table III shows the simulated instrument time and the total flying time accumulated by each subject during the case study.

THE FLIGHT TEST

Period 6 was devoted to testing the results of the instruction which the subject received during Periods 2, 3, 4, and 5.

The three phases of the flight test, briefly described, were:

Phase 1 — The subject was given a series of three problems, each one involving performance of the complete task of encountering instrument weather, making the transition from cruise to slow flight, making a 180-degree turn, and executing a controlled descent. No assistance was given by the instructor except such information as would have been available to the subject on the radio, i.e., weather reports. The subject was graded primarily on his ability to complete the entire problem without approaching an incipient dangerous flight

TABLE III

Subject Number	Simulated Instrument Time	Total Flight Time
1	1:54	4:18
2	1:54	4:42
3	1:48	3:54
4**	2:36	5:18**
5	2:18	4:06
6	1:30	3:42
7	1:36	4:00
8	1:54	4:12
9	2:00	4:36
10	1:30	3:24
11	2:24	4:36
12	2:30	4:54
13	2:06	4:00
14	2:06	5:00
15**	2:54	5:42**
16	2:24	4:36
17	2:06	4:24
18	1:54	4:06
19	1:48	4:12
20	1:54	4:42
Average	2:03	4:25

** Two subjects were given one extra flight (5X).

condition and to complete the 180-degree turn within 30 degrees of the desired track.

Results of Phase 1 — The twenty subjects were given three trials each, a total of sixty trials. Fifty-nine of the sixty trials were completely successful. Subject 17, on the first of his three trials, failed to include step 5 which involved adjusting the prop pitch and power to the marked position for maintaining altitude. The omission of step 5 resulted in a steady loss of altitude which was continued during the 180-degree turn and after the airplane was established on a reciprocal course. The instructor called the attention of the subject to the loss of altitude at approximately 100 feet above ground. Under the definition of an incipient dangerous flight condition this trial was unsuccessful.

On the next two trials this subject's performances were successful.[12]

Phase 2 — Upon completion of the three simulated problems, each subject was informed that he had completed the course and that he had met the required standards. The subject was then invited to test any theory or idea which he believed might be a better solution to the problem. There were two reasons for including this in the final flight: (1) the investigators were genuinely interested in any suggestions which the subjects might have to offer, and (2) it provided the subject with an opportunity to try out his own "pet" ideas on the subject.

Results of Phase 2 — Every subject accepted the invitation to a fourth trial. Only two of them, however, attempted new variations beyond those which they had been taught during Periods 2, 3, 4, and 5. In these two cases the subjects expressed the idea that the oscillations which occurred during the performance of steps 1 through 5 could be dampened by the pilot if he were allowed to keep his hands on the control yoke. In both cases, upon trial, the attempted dampening was out of phase with the proper correction and resulted in even more extreme oscillations. The two subjects realized this fact almost at once and consequently both subjects immediately released the yoke and continued through the remainder of the steps with "Hands Off."

Phase 3 — This phase of the flight test was not included in the study of the twenty cases but was added to the experiment in an effort to satisfy one of the most consistent objections raised by pilots inquiring about the project. Their objection was that successful completion of the 180-degree course might encourage the subjects to use this system to fly through instrument weather rather than to get out of instrument weather.

Briefly, this phase involves asking the subject to demonstrate his ability to fly under simulated instrument conditions to a specific geographic location. This request is realistic since this objective can be accomplished if the pilot is a qualified instrument pilot and if the geographic location is equipped with appropriate radio navigation aids.

Noninstrument and 180-degree turn pilots will not be able to accomplish Phase 3. This test will effectively demonstrate to them,

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[12] Under actual instrument weather conditions the pilot would probably have "broken out" and would then have been able to continue visually. Even in zero-zero conditions there was doubt as to whether a fatality would have resulted since the aircraft speed was low, and the rate of descent was slow and under control.

however, that instrument flying, as distinguished from the 180-degree turn emergency system, involves considerably more knowledge and skill than that which is offered in the 180-degree turn syllabus.

Application to Other Types of Airplanes

GENERAL

Tests of the technique were tried in a variety of light, single-engine airplanes. Analysis of these trials proved that the technique can easily be adapted to most airplanes now available to the civil, nonprofessional pilot. Other than on the Beechcraft Bonanza, the technique was not employed on airplanes with retractable gear or with controllable-pitch propeller, nor on any so-called two-control, or rudderless, airplanes.

HOW TO PROCEED

The general order of the steps for tailoring the technique to other light aircraft will not vary except in those cases where the airplane does not have retractable gear or a controllable propeller. In those cases, the appropriate steps are (1) hands off, (2) adjust power, and (3) adjust trim. In all cases the net result of the tailoring is to find the trim-tab position and the power setting. These are found as follows:

(1) *Determine the loading condition.* This step involves a decision as to the most frequently used loading condition of the airplane. This may be solo with no baggage, with one or with two passengers, or with a maximum gross load. The term "most frequently used loading condition" is important here; if there is any doubt as to the load most frequently carried, the maximum load should be used.

(2) *Find the best airspeed.* This step is for the purpose of determining the best airspeed for the particular airplane. The best airspeed will be near the recommended approach speed. It should be slow enough to reduce the possibility of excessive G loads, but not so slow that the roll (lateral movements) of the airplane cannot be readily controlled through the rudder.[13] At a safe altitude, properly loaded, the throttle should be reduced below the cruising

[13] In some instances it was found that 5 m.p.h made a great deal of difference in the roll response obtained — the Cessna 170, for example, was very slow to respond to a rudder roll at 75 m.p.h. but at 80 m.p.h. excellent response was obtained.

position.[14] The airplane should be slowly trimmed to fly hands-off at the desired slow speed. Once the speed is trimmed in, several unusual attitudes should be attempted — hands still off the yoke — and special attention devoted to the response obtained with rudder only. The severest trial is to test roll recovery from a bank in excess of 70 degrees. If positive response is obtained the airspeed is suitable. If the airplane has retractable gear, it is advisable to have it in the "down" position during the foregoing trials.

(3) *Mark the trim-tab position.* This mark should be made only after several trials have definitely proved that rolling the trim tab to this point will always result in the desired speed after the airplane has completed two or three oscillations. These trials must also be made with hands off the yoke. Once the correct trim-tab position is found it should be plainly marked.

(4) *Find the power setting.* This step is to determine the exact power setting required to maintain altitude at the desired speed. If the airplane has a controllable propeller, it should be set in the low pitch (high r.p.m.) position. The altimeter and rate of climb, if one is installed, should be observed while the throttle is slowly adjusted to the position for maintaining altitude. Do not be satisfied with a power setting which will *almost* hold the altitude. The airplane should be allowed to fly for several minutes, hands off, with fine adjustment made in the throttle setting to bring the altitude into balance. Once the power position, or throttle setting, is established it should be prominently marked. A piece of tape cut to the size and shape of the indicator hand and pasted on the dial of the tachometer or manifold pressure gauge makes a suitable mark.

(5) *Check settings.* This is a complete test for the accuracy and reliability of the speed, trim, and power determined in the preceding paragraphs. The airplane should be placed in normal cruising attitude with cruising power and trim, and the speed allowed to come up to normal cruise. The following steps should be completed without hesitation between steps: (a) hands should be taken off the stick or yoke, (b) gear lowered,[15] (c) power re-

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[14] Exact setting is not important so long as the power is below cruising but above idling.

[15] Any airplane other than the Beechcraft Bonanza should be checked with the manufacturer to determine whether the gear can be lowered safely at cruising

duced, (d) trim tab set, and (e) pitch and power adjusted to setting. The airplane will go through a series of two or three oscillations. When the oscillations are completed the airplane should have settled down to the predetermined airspeed with altitude maintained after a gain of one or two hundred feet.

One complete check of the settings is not satisfactory. Additional trials will result in finding a "timing" or "pace" which will create a smooth transition from cruise to slow flight conditions. In the Bonanza there is a "pace" which gives a smooth transition with only one oscillation. A small amount of practice and experimentation will establish the "pace" for the particular airplane.

SPECIFIC AIRSPEED RECOMMENDATIONS

The airspeeds recommended for light aircraft tested during the experiments are:[16]

Aeronca 7AC	65 m.p.h.
Piper Vagabond	70 m.p.h.
Cessna 120 and 140	75 m.p.h.
Piper Tri-Pacer	80 m.p.h.
Cessna 170	80 m.p.h.
Stinson 150	85 m.p.h.
Bonanza	95 m.p.h.

No unusual or extraordinary flight characteristics were experienced in any of the foregoing airplanes.

The technique will require considerable modification in order to be applied to a two-control airplane such as the Ercoupe. The technique has not been tested in either a Navion or a Bellanca, but it is believed, on the basis of previous flight experience with these airplanes, that the technique could be adapted to them.

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speed. Mr. D. H. Williams, Project Engineer of the Ryan Aeronautical Company, says of the Navion, "As you know, the Navion airplane is placarded against lowering the gear and flaps above 100 m.p.h. Although 100 m.p.h. is the C.A.A. approved speed, we flight test all production airplanes at 120 m.p.h. Operation above this speed is not recommended on landing gears equipped with fairings. . . . The older Navion airplanes, not equipped with fairings, were qualified at a speed of 160 m.p.h."

[16] These speeds are approximately twice normal stalling speeds. They were selected as representing the speeds which, in addition to positive control, represent the most satisfactory speeds in turbulence, which might cause unexpected stall problems, and which, at the same time, provide the optimum protection against excessive G loads on the aircraft structure.

Conclusions

The following conclusions were reached upon examination of the twenty cases studied:

(1) Pilots who have had no previous experience with instrument flying cannot expect to survive their first experience under actual instrument conditions, except by mere chance.

(2) The 180-degree turn curriculum, properly organized and directed, will materially increase the chances of surviving the first experience with unexpected instrument weather conditions.

Instructor Guide

Instructor Guide to the 180-Degree Turn Procedure

The 180-degree curriculum[17] consists of six one-hour periods. Each period is divided into preflight discussion, the actual flight, and postflight discussion. The preflight discussion prepares the student for the flight. The flight section includes a brief description of what should be accomplished in the air. The postflight discussion emphasizes the results of the flight period. It is the intent of this syllabus to suggest a method for teaching the 180-degree turn procedure.

The instructor will need to be extremely selective about "what" and "how much" information he gives the student. He should make the student conscious of the problems of instrument flight, teach him how to turn out of instrument flight conditions successfully, and encourage him to continue his education and training as a safe and qualified pilot.[18]

In the following syllabus the aircraft used is a Beechcraft Bonanza. For purposes of realism both the preflight and postflight discussions are in the first person and are suggested explanations which instructors may find useful.

Period 1

Purpose: To demonstrate to the "contact" pilot that he cannot control his aircraft under instrument flight conditions.

PREFLIGHT DISCUSSION: APPROXIMATELY 10 MINUTES

"The average pilot uses visual references on the ground to tell him what the airplane is doing. When he loses sight of the ground, or any outside cue he may be using to control the attitude, he is unable to control the aircraft, i.e., he no longer knows whether he is turning, going up or down, or flying straight and level. He cannot control the plane from the information given him by his physical sensations which, more often than not, give false information. In other words, the 'seat of the pants' is not reliable. A pilot cannot fly in the clouds without knowledge of instrument flying.

"In an effort to decrease the appalling percentage of fatal light aircraft accidents in civil aviation due to pilots attempting to fly in instrument weather conditions without the necessary skill, the University of Illinois was commissioned by the AOPA Foundation, Inc., to find a

[17] Also spoken of as the "emergency turn" or "self-saving" curriculum.

[18] If the student owns his airplane, he should take his instruction in it after the instructor has established the procedure for that aircraft.

simple solution whereby the average 'contact' pilot could control the aircraft well enough to 'get out of' bad weather and return to a point where he could see the ground. In an effort to find a way to do this, the University of Illinois has devised a six-period curriculum.

"In the first period you will (1) familiarize yourself with the plane and (2) have presented to you the basic problems of instrument flight. On this first flight, after a few turns, a stall, and slow flight have been completed, you will put on blue goggles. These goggles in combination with amber-glass windowshields will keep you from seeing outside while enabling you to see the instrument panel inside the plane. You will attempt to maintain straight and level flight. When you approach a dangerous speed or attitude, you will be told to lift your goggles and observe while the instructor recovers and returns the plane to a normal flight attitude. If your reaction is normal, your attempts at flying instruments will be dramatically unsuccessful."

FLIGHT: APPROXIMATELY 30 MINUTES

The flight instructor should give the student as much information on the plane as he can assimilate without detracting from the basic problem — that of giving the student a dramatic demonstration of his inability to fly the plane "on instruments." It is important for the student to feel that he can control the aircraft adequately, so that he will not be able to use his lack of familiarity with it as an excuse for failing to fly successfully in the simulated instrument setup.

The flight is divided into two parts. The first part is familiarization, making the student feel at home in the aircraft. Give enough of a cockpit checkout to acquaint him with the instruments. Identifying the basic ones he has used in his previous flight training helps to accustom him to the strangeness of a new aircraft. Let the student do as much flying as possible without confusing him. Let the student actually push, punch, and move the controls and switches. By doing most of the thinking for him and using the "talk through" routine, there is little that the student won't be able to do. As soon as practical after take-off turn the controls over to the student and let him continue the climb out. After leveling off, direct him to make a couple of 90-degree turns. Follow this with slow flight, then a stall. Emphasize that these maneuvers are made with the sole purpose in mind of familiarizing him with the aircraft and that there is no intention of grading his technique. Try to put him at ease; the more "at home" he feels with the instructor and with the aircraft the more impressive his instrument experience will be to him. Trying to impress the instructor, trying to learn too much about the plane all at once, or other distracting factors will serve to lessen the effect of his instrument attempt.

After the stall resume cruising flight, making sure that all the necessary lights are turned on. Have the student put on the blue goggles while you fly the plane. Let him become accustomed to the blue goggles and the restricted light. Give him every "break" to make sure that he is ready for his try at "instruments." You might say, "OK, you are in the overcast. Use any means you wish to keep the aircraft under control. Try to hold a course flying straight and level. It's all yours."

The student should not be allowed to go beyond certain safety limits in the effort to convince him he cannot fly instruments. These limits, arbitrarily set, are:

(1) *Stall.* An unintentional stall on instruments should convince anyone of his inability to control the plane successfully.

(2) *Airspeed of 185 m.p.h.* If the instructor starts a recovery at 185 m.p.h., in all likelihood the speed will reach 200 m.p.h. Do not exceed the redline limit of 202 m.p.h.

(3) *Altitude of less than 500 feet.* An impending crash with the ground is an excellent "convincer."

(4) *Prolonged loss of direction.* It is helpful to draw the track of the student's attempt to fly instruments. Because the student is unaware of the gyrations being made, it is impressive for him to see subsequently the aircraft track as drawn by the instructor. The track should be drawn as near to scale as possible.

To accomplish the purpose of the first flight the instructor must let the student go as far as safety permits. Usually, the student will end up in a high-speed spiral dive. He will combine the factors of high-speed, bank, dive, and proximity to the ground in a dramatic effect.

Normally, the lower the altitude at which the student makes his instrument try, the more spectacular is his failure. However, the instructor must know the limitations of the aircraft. While he should not exceed the bounds of safety before recovery, the closer the aircraft comes to the limitations of altitude, airspeed, etc., the more impressive is the result to the student.

If the student loses control of the plane in a very short time, say 30 seconds, it is advisable to offer him another try. Sometimes a student will lose control so quickly that he may not realize the seriousness of the problem. He may rationalize, "I didn't have a chance to get settled."

Three tries are generally the maximum before going on to the rest of the course. The student first must be convinced that he cannot fly instruments.

After completion of the simulated instrument part of the flight the instructor will take over and fly back to the field. On the return trip, discuss the student's efforts and answer his questions. The student may need to relax as the experience of the "unknown" takes a lot of nervous energy. More will be accomplished by discussion on the ground where he will be ready to consider the problem seriously.

POSTFLIGHT DISCUSSION: APPROXIMATELY 20 MINUTES

"Now let's take a few minutes to talk over the flight and see what happened. Let's examine the problem of the tremendous load one can impose on a plane in a graveyard spiral maneuver. Occasionally you read in the paper that a farmer saw a plane come diving out of the overcast, right itself momentarily, and then he saw a wing 'fall off.' Wings do not 'fall off' airplanes. They can be 'torn off' but they do not 'fall off.' Without being too technical, I would like to go over some of the structural limitations and the load factor considerations which every pilot should know about his airplane.

"As you and I are sitting here there is a load of one G on us. That is, I have one times 168 pounds acting on me right now. You have one G or one times 170 pounds acting on you. In straight and level flight we have one G or one times the force of gravity acting on us. Every pilot should realize that the load on an airplane increases as the angle of bank is increased in a turn. This extra load is due to centrifugal force. But how much does this centrifugal force add to the load of our plane when it is banked? Let's examine a table.

Degree of Bank	Load (G) on Wings
0 (Level Flight)	1 G
50	1.56 G
60	2 G
70	2.92 G
80	5.75 G
90	Infinity

"The above table holds true for a coordinated banked turn while holding a constant altitude. Note how the effective load on the wings increases with the change of bank. For example, in a 60 degree bank our Bonanza, instead of weighing 2700 pounds, weighs 5400 pounds. This banked condition is only a part of the uncontrolled downward spiral you were in.

"Try to picture now what you would have done had you actually popped out of an overcast headed right at the ground. The instinctive reaction is to pull back on the stick — and if you are only a few hundred feet above the ground when you come out of the clouds you don't have much choice, do you? You've got to make a quick pullout or you'll hit the ground. Let's look over a simple formula covering this exact situation which assumes a 90-degree curve could be flown instantaneously.

$$\text{LOAD IN ABRUPT PULL UP} = \left(\frac{\text{entry speed}}{\text{normal stall speed}}\right)^2$$

"Take your first attempt at flying instruments as an example. Your entry speed, or the speed you had when you broke out of the overcast (when you lifted the blue goggles), was 200 m.p.h. The normal stalling speed of the Bonanza with the wheels and flaps up is 65 m.p.h. A little figuring shows that to make an abrupt pull up under those circumstances would have loaded the plane with approximately nine Gs. That's enough to tear an airplane apart. The Bonanza has a limit load factor of 4.4 Gs. That is, the Bonanza, according to the *Handbook,* is perfectly safe under a load of 4.4 Gs. It has an ultimate load factor of 6.6 Gs; at this point the plane has a perfect right to come apart. Your reaction can very well be, 'Why don't they build them stronger?' The fact is that the Bonanza has a higher load limit than most commercial airliners in operation today. The Civil Air Regulations allow transport category airplanes (DC-3, Constellation, etc.) to have a maneuvering load factor as low as 2.5 Gs. Considering the added load during a bank, plus the load imposed in an abrupt pull up, it isn't difficult to see that a pilot can tear a plane apart. This condition can and often does exist for noninstrument pilots emerging from an overcast in a high speed spiral dive.

"The whole purpose of this first flight was to show you that you cannot control the plane unless you have some outside visual reference. You are not an instrument-rated pilot. Don't get the idea that instrument flying is for supermen. That's not the point at all. Ability to fly on instruments is simply a skill acquired through training and practice. But without that skill it can be fatal to try to fly 'on instruments' —

as you saw from your attempts. Ideally, every pilot should continue his training to become a qualified instrument pilot. This not only is the best life insurance he can get, but it also enables him to utilize his aircraft more effectively. However, we know that not every pilot has the time or the money to spend in getting an instrument rating. Yet, sooner or later, if a pilot flies long enough, he is likely to encounter weather that he was not expecting and will find himself 'on the gauges.' It is for this situation that we have devised an emergency self-saving system, a procedure to 'get out of' the bad weather and back to where you can see the ground."

Period 2

Purpose: To introduce the emergency self-saving procedure.

PREFLIGHT DISCUSSION: APPROXIMATELY 15 MINUTES

"In the first period, we saw the problem of instrument flight. Just the realization that a problem exists puts us ahead of many pilots who think that if they ever should get on instruments, somehow or other they would be able to get through all right. We know from our first flight experience that this is not so. A person without instrument knowledge and experience simply cannot fly the plane once he has lost all outside references. For this reason we are proposing an emergency procedure that a 'contact' pilot could use should he get caught in a storm or overcast. We don't say this is the only solution to the problem, or even that it is the best solution. However, it is a solution and one that, if followed properly, will work. It could save your life.

"Your first thought on encountering instrument flight conditions should be to get positive control of your plane. With that end in sight let's first examine the steps of the emergency self-saving procedure. The steps will be placarded in a prominent place on the instrument panel. Your job when you lose visual reference outside the plane will be to read and do the five steps.

"The placard in our Bonanza reads:

Emergency	
1. Hands off	Center Needle
2. Gear down	Center Needle
3. Throttle back	Center Needle
4. Trim to mark	Center Needle
5. Throttle 17" r.p.m. high	Center Needle

"(1) *Hands off.* This step is essential to the technique. The noninstrument pilot is as likely to make the wrong control movement as the right one when he encounters instrument flight conditions. By taking his hands off the stick or control wheel he will avoid 'man handling' the plane into any unusual attitudes. The hands off technique will allow the plane to make use of its inherent stability and will allow it to seek out a predetermined airspeed. After you have done this a few times without the goggles and have seen the result, you will build up confidence in the plane's doing the right thing, and later on in the course you won't want anything to do with the control wheel. You'll know that the inherent stability of the plane will do a better job than you can do.

"If you were capable of using the wheel under instrument flight conditions and could interpret the instruments well enough to know what to do, then you would have no need of 180-degree instruction in the first place. But since you are not an instrument-rated pilot and cannot, without training and practice, interpret the instrument readings properly then it is best to rely on the stability of the aircraft to avoid maneuvering the craft into radical positions from the false information of your senses.

"(2) *Gear down.* Lowering the landing gear helps slow the plane down. One of the problems we have to solve is the transition from cruising speed to a positive control slower speed. Lowering the landing gear is a positive and easy way of reducing the speed.

"(3) *Throttle back.* The system still 'works' whether the throttle is closed all the way or not touched at all, but the system improves when the throttle is reduced to partial power — power just above idling.

"(4) *Trim to mark.* The trim tab is moved to a predetermined mark. That mark is the trim setting which will give us 95 m.p.h. in the Bonanza. Our goal is to get the approximate approach speed of the aircraft. This is a speed that is well below the high speed of the 'graveyard spiral,' slow enough so that it is difficult to build up much of a G load, yet a speed that gives us positive control.

"(5) *Throttle 17 inches, r.p.m. high.* You can see the desirability of setting the throttle to a position that will enable us to hold altitude, neither gaining nor losing. That is exactly what we have done. A mark put on the manifold pressure gauge gives the power setting that will hold a constant altitude. It is marked by a piece of tape and happens, in this case, to be 17 inches of manifold pressure. This must be predetermined for every airplane. It is desirable to have the propeller in the full low pitch or high r.p.m. position. In effect this gives us a fixed-pitch propeller. Any intermediate propeller pitch position would be too difficult to arrive at accurately due to the constant variation of the r.p.m.'s as the plane goes through its initial oscillations.

"In the interest of clarity the continuous step of centering the needle is discussed last. In practice it most certainly does not come last, nor does it come only at the first part. Attempting to keep the airplane 'straight and level' by keeping the turn indicator averaging out in the center is of paramount importance, and it must be a *continuous* operation. It is this instrument which indicates whether the airplane is turning or going straight. The turn indicator or needle is controlled with the rudder pedals; e.g., if the needle is to the left of the center mark it indicates that the airplane is turning to the left. Right rudder pressure will roll the airplane back to straight and level flight. The needle will always indicate any turn the airplane makes. We have no interest in the ball part of the instrument and from here on will ignore it."

AIRSPEED AND ALTITUDE

"It is vital that you understand that the airspeed is controlled by the trim setting and that the altitude is controlled by the power setting. Let's review some basic concepts with a hypothetical flight in an Aeronca Champion. In the air, suppose that you control the throttle and I control the stick. Flying in this manner, I challenge you to do anything in your power to keep me from holding 65 m.p.h. Your first reaction may be to put on full throttle. Obviously all that is necessary for me to hold 65 m.p.h. is to give a little back pressure on the stick and enter a climb at 65. What about reducing the power to idling? In this case, I let the nose drop and we keep an airspeed of 65 m.p.h. in a glide. The moral, of course, is that the airspeed is controlled by the stick. For our purposes we can substitute the trim tab for the stick.

"In the same vein, I might say to you, OK, same rules, I'll take the throttle, you take the stick. Now let's see you hold your altitude. When I set the power at idling is there anything you can do to the control stick to keep the airplane from descending? Absolutely not. The throttle does control the altitude."

WHAT INSTRUMENTS

"This technique was devised to make it as universally applicable as possible. Civil Air Regulations say that every airplane must have an airspeed indicator, an altimeter, a magnetic compass, and certain power instruments. For such an extremely limited instrument experience as we are proposing, some kind of attitude instrument is necessary. The turn indicator is used here since it is extremely reliable and comparatively inexpensive. Presumably other instruments might be added, but for our purpose we shall use only the above."

MECHANICS PLUS TECHNIQUE

"Think of the technique as being divided into two parts: (1) The process of getting the airplane under control is purely mechanical. You read the placard and do what it says. Certain switches and controls must be punched or pulled. No particular skill is involved. Anyone who can read can do the mechanical part of the procedure. (2) The technique involved in the procedure comes in learning to interpret the turn indicator and the magnetic compass. The majority of our time will be spent in learning to visualize what those two instruments are telling us and in learning how to control them.

"In the mechanical procedure you actually eliminate several instruments that you normally have to watch. By setting the trim we eliminate airspeed consideration since we know that the plane is going to seek out 95 m.p.h. Setting the power lets us forget about the altimeter until time to descend. In effect we have eliminated everything but the turn indicator and you can give this instrument your full attention. An occasional glance at the magnetic compass will give the directional information you need."

OSCILLATIONS

"In the transition from cruising flight to slow flight you very likely will experience pitching oscillations. How severe these oscillations are will depend on how smoothly you do the outlined steps, i.e., the mechanical part of the procedure. The oscillations in themselves are not dangerous. As long as you complete the five steps within a reasonable length of time, and as long as you exercise a moderate amount of control over the turn indicator, the airplane will not reach an excessive speed — in fact, the highest speed is almost sure to be the speed at which you started — nor will the aircraft stall. The oscillations may make it more difficult to control the turn indicator with the rudders, but they are not dangerous."

RUDDER CONTROL

"Let's briefly touch on the use of the rudder to control our turns and straight and level flight. When you learned to fly you were taught that by changing the lift force acting on an airplane you could bank it and in so doing, turn the plane. You learned that to make an airplane bank you use the ailerons in conjunction with the rudder. Are we teaching you anything new? Is this a radical departure from what you learned? Decidedly not. What happens when you apply rudder pressure? Let's say that you exert pressure on the right rudder. The rudder controls the yawing motion about the vertical axis so when you push right rudder the nose of the aircraft goes to the right. As the nose moves, so must the wings since they are attached to the same plane. But in the same amount of time the left wing must go farther than the right wing since it is going around the outside of the circle. This means that the left wing is going faster than the right wing. Increasing speed is one way of increasing lift, so in this case the left wing momentarily gets more lift and the airplane goes into a bank. Now part of the total lift force is acting to the side and gives the force necessary to turn.

"This is nothing new; the same principles you learned when you started flying still hold true. Bear in mind that this whole procedure is a 'gimmick' designed to save your life. If it is easier and safer for us to make a 'sloppy' turn in order to get the job done, then that is the best way under the circumstances. All turns will be shallow ones and experience has shown that the altitude lost will be negligible."

PREFLIGHT DISCUSSION CONTINUED IN THE AIRPLANE

"Let's take a minute here in the airplane to go over the procedure and be sure that we have it in mind. We will go over it several times before we start the engine and again while we're checking the plane at the end of the runway, and then several more times in the air before you put on the goggles. By then you will find that you are familiar with the steps and won't have any difficulty in doing them. Here is the placard on the instrument panel; let's take the steps individually.

"Needless to say you will be making a constant effort as you go through the procedure to center the turn indicator. Without this vital continuous step the system is useless. This does not mean that you should hesitate or pause between steps to get the needle perfectly in the center. Rather it means that as you are going through the system, if you see that the needle is off to one side, indicating that you are in a turn in that direction, you should apply opposite rudder pressure to start the plane back to a level attitude as you continue with the steps. After you have completed the steps then you can concentrate your attention exclusively on the turn indicator.

"(1) *Hands Off.* Take your hands off and leave them off. You have no further need of the control stick. It doesn't hurt to be a bit dramatic about it. Let go of the wheel as though you really meant it.

"(2) *Gear Down.* Reach over and put the landing gear switch in the down position. Once you've done that go right on to the next step. There is no need to watch the gear position indicators.

"(3) *Throttle Back.* How far back? Ideally you should throttle back to partial power, slightly above idling. A manifold pressure of somewhere between 10 and 15 inches is fine. However, do not watch the manifold pressure gauge. Without hesitation move the throttle back several inches to what you consider the right position. It will take only a few times before you will be able to put it right where you want it without taking time to check on the MP gauge. Actually it isn't vital to the procedure to set the throttle accurately, but it makes the system much smoother; this in turn makes it easier for you to control the turn indicator. It is important to go immediately to the next step of putting the trim tab to the mark, since the steps of putting the gear down and the throttle back will give the nose of the plane a downward pitching movement.

"(4) *Moving the Trim.* Moving the trim to the mark will partially offset the gear down and throttle back steps, and, if done properly, will help in a smooth transition from cruise to slow flight. As was explained the trim tab is predetermined and in the Bonanza is set to give a speed of 95 m.p.h. Put the top edge of the green sector of the trim tab indicator at the top of the trim tab indicator window. This is an easy way to get the desired setting. Move the trim tab wheel slowly toward nose up until you see the division between the green and white sectors on the trim tab indicator. Then move the top of the green to the top of the window. Move the trim tab wheel slowly. Moving it too quickly is the same as abruptly pulling back on the wheel. Moving the tab too quickly is not dangerous, but there will be steeper oscillations and it will be more difficult to control the turn indicator.

"(5) *Throttle to mark, r.p.m. high.* There is a reason for taking step 5 in this order. If the throttle is set at only slightly over idling, and you try to change the pitch of the propeller to high r.p.m.

(low pitch), you will find that it may take as long as 30 seconds or more. The best technique is to advance to 19 or 20 inches of manifold pressure. Then, when you change the pitch of the propeller to get high r.p.m.'s, you will find that the manifold pressure will drop and you will have approximately the correct power setting, namely 17 inches. It may be necessary after changing the propeller pitch to make a slight adjustment of the manifold pressure. Line up the MP needle with the tape indicator on the face of the MP gauge and you will have the right setting for holding a constant altitude."

GENERAL COMMENTS

"You will find it helpful to read the steps aloud as you go through them. Actually talk yourself through the proper procedure. Talking to yourself makes you conscious of what you are doing. Anything you can do to make yourself deliberate and positive will give you more confidence.

"Go through the procedure now, actually touching the landing gear switch; move the throttle and trim tab; go through the steps several times; get yourself thoroughly familiar with the various controls.

"Now let's pretend that you are on the way to Chicago. We're flying along contact; you have your hand on the wheel and your feet on the rudder pedals. Somewhere in the vicinity of Kankakee we start to get into weather that doesn't look good, but we have important business in Chicago so we are determined to get there. That's our first mistake, of course. It is folly to 'push' the weather. Look out your side of the cockpit. You can't see the ground. Look over through my window; nothing but milky white clouds. We're in trouble. We're 'on instruments.' Now is the time for our emergency self-saving system. OK, fire away." (Student, still on the ground, goes through the mechanical procedure.)

"Bear in mind that you should do the steps as quickly as you can comfortably do them. It is a purely mechanical process. Read the placard and do what it says. Think of the procedure as a 440-yard run. It isn't a 100-yard dash; that is, it isn't necessary to hurry or get excited. Yet it isn't a two-mile run either. Go about the steps in a business-like fashion and get the job done. Do them quickly; pace as you would in a 440. Let me emphasize again that as long as you do the steps you'll not lose control of the aircraft. But, if you take too long to do them, or do them in an erratic or hesitant fashion, you will lose altitude or set up severe oscillations. It's not difficult to get the job done properly. Read the placard; do what it says; and then you are free to concentrate on the turn indicator."

FLIGHT

As a general rule, let the student do the flying. Make him think for himself as much as possible. However, when he appears to be tiring, it is good procedure to take over for a minute. Let the student make the take-off. Climb-out is made to an altitude of approximately 2000 feet above the ground. At this point the instructor should take the controls and make a visual demonstration of the procedure to the student. The purpose is to prepare the student for what to expect and to provide him a model on which to pattern his attempts. The instructor should make an effort to complete the procedure as smoothly as possible, repeating the steps aloud as he does them. After the steps have been completed the instructor should allow the plane to go through the oscillations. He should call the attention of the student to the fact that the plane does settle down to a constant altitude and that the airplane does seek out the predetermined 95 m.p.h.

Don't hurry this first demonstration. The student should have every opportunity to verify what he has been told by watching and feeling the actions of the airplane. Point out to the student that there is no danger or difficulty in taking the hands off the wheel; the plane can easily be controlled by use of the rudders.

Questions should be encouraged. The initial demonstration will normally require 5 minutes. If the air is rough, it is best to continue the climb until the air is smoother. The first demonstration should be as clear as possible, thereby convincing the student that the inherent stability of the aircraft will take care of the oscillations. If the procedure is accomplished properly, the transition from cruise to slow flight can be made with very little oscillation.

The instructor should return the plane to normal cruising flight and turn it over to the student, who now will visually attempt the self-saving system. At first the student may be apprehensive. If he is hesitant, the instructor should talk him through. Pointing to the placard and reading aloud the steps may help him to get started. On the student's first visual try, he should be allowed to take enough time to convince himself completely of the plausibility of the system. Let him control the attitude with the rudders and if there are any oscillations be sure that he "rides" them out in order to prove to him that the plane will eventually seek out the predetermined airspeed and will then hold a constant altitude.

The student should repeat the procedure three or four times without the goggles. After the first time, if he is convinced that the aircraft will react the way he has been briefed, it is not necessary to carry each practice attempt to its ultimate conclusion. If the instructor believes that more knowledge will follow by interrupting the student at the time of error, he should do so; e.g., if the student rolls the trim tab the wrong way it may be best to start over again. Allowing the student to complete the procedure and then pointing out errors is a most effective method.

After the instructor has demonstrated the system once, and the student has practiced it three to five times visually, the student should have the system well enough in mind to try it under the simulated instrument condition. The transition is more easily made if, after the last time through the visual trials, the student puts on the goggles and practices controlling the plane with the rudders. Now, for the first time, he will have no outside cues as to the plane's attitude and will have to rely solely on the turn indicator. It will take him some time to get used to the idea and to the limited light available through the blue goggles.

Let the student practice flying the plane straight and level; then permit him to make gentle turns. Remember that the turns are to be made at ¾-needle width, with a maximum of one needle width. Stress that the turns should be made with a shallow bank. As the student improves in his efforts to control the needle it is helpful in teaching and will build confidence if the instructor will occasionally let the student lift his goggles and observe the attitude of the aircraft. In other words, if the turn indicator indicates that the plane is in a turn, let the student see what is happening. If he thinks the plane is straight and level when in reality it is in a turn, nothing is so convincing as lifting the goggles and observing the attitude.

After a few minutes of controlling the plane under the goggles, the student should lift the goggles and either he or the instructor return the plane to a normal cruise. Now the student attempts the whole operation. The instructor should strive from the beginning to make the problem of "accidental instrument flight" as realistic as possible. In the cruising attitude the student puts on the goggles, then (1) gets the aircraft under control and (2) with the instructor acting as the compass, makes a turn to the reciprocal of his original course, and (3) with information given him by the instructor begins a normal let-down. Again, in the normal let-down it is important to call to the student's attention that although he is gradually losing altitude, the airspeed remains approximately 95 m.p.h. Also, he should be given a "look" from under the goggles to see his descending attitude in relation to the ground.

CONTROLLING THE TURN INDICATOR

The technique of controlling the turn indicator must be taught almost wholly in the air.

(1) *"Averaging" the turn indicator.* It is important that the student understand that proper control of the turn indicator is largely a matter of correct interpretation. In order to control the turn indicator correctly it is necessary to average out its readings. It is not an easy instrument to read. The needle fluctuates from side to side, especially in rough air, and the problem is to read it in terms of an "average." The student must understand that in order to maintain straight and level flight, he must make the needle travel the same amount on each side of the center mark. It doesn't make too much difference how much the needle is off center. Rather it is a problem of *how long* it is off center. Even ⅛ of a needle width if not corrected will, in a matter of minutes, give a 180-degree, even a 360-degree, turn. At some time during the course the instructor should demonstrate, with alternating rudder pressures, how the needle can swing from side to side, hitting the stop on each side, with the airplane actually still in a straight and level flight attitude. In straight and level flight the object is to control the rudders so that the needle averages straight up. The same is true for a turn, only now, instead of averaging the needle in the straight up position, it is averaged ¾ of a needle width on the side of intended turn.

(2) *Parallax.* Parallax is the apparent displacement of an object as seen from two different points. Depending on the position of the turn indicator in the plane, parallax may well be a factor with which to contend. In this study the turn indicator in the Bonanza was just to the right of the center line on the instrument panel. Since the student was seated in the left-hand side it was difficult to read the turn indicator. If the student "centered" the needle without considering parallax, he would actually have the needle slightly to the left of center giving the plane a slight turn to the left. The student must mentally project himself directly in front of the needle to control it properly. If a student always

errs to the left during practice, in all likelihood he is not making sufficient correction for parallax.

(3) *Torque.* Another consideration in the technique of controlling the turn indicator is torque. The designer rigged the plane so that it could be flown without right or left rudder pressure at cruising speed. In the self-saving system the airplane is trimmed to seek out the approximate approach speed. In situations where the air speed is comparatively low and the power is comparatively high (such as in take-off or climb), the torque effect is noticeable. Normally this is taken care of by additional right rudder pressure. So, in the process of controlling the plane with the rudders it is quite possible that the student will maintain some right rudder pressure to keep the needle averaging out in the center. This is normal since the speed is well below cruising, with almost cruising torque effect.

Period 3

Purpose: (1) To explain and demonstrate the peculiarities of the magnetic compass so that the student will understand and be able to use it as his sole direction-indicating instrument. (2) To put together the information the student has learned to date, so that he thinks and acts on the problem as a whole.

PREFLIGHT DISCUSSION: APPROXIMATELY 25 MINUTES

"Let's briefly review our problem: We are on a cross-country flight. In spite of our best efforts we find ourselves in instrument flight conditions. The first thing we'll do is to get the aircraft under control by going through the steps. But maintaining control of the plane isn't enough. We have to find our way back to good weather. The problem boils down to four considerations:

(1) *Control.* This involves the process of getting the plane under control by doing the self-saving steps.

(2) *Direction.* After the steps have been completed there is no guarantee that the plane is still on the original heading. This will depend on how well the pilot has done the steps. However, the original heading is not of particular importance as long as we can find out what heading we are now on. The second direction we are interested in is the reciprocal heading to our original course. Presumably we could see the ground where we came

from and it is our desire to get back there. So the two directions we want to know are:

(a) What direction are we going now?

(b) What direction do we want to go?

(3) *Turn.* We know which way we're going now. We know which way we want to go. Now the problem is to turn to the desired heading.

(4) *Let-down.* If after a reasonable time we don't break out of the instrument flight conditions by flying back towards the good weather we may need to consider a let-down.

"That's the problem as a whole. Now let's specifically examine the instrument that will give us the direction information vital to our survival."

MAGNETIC COMPASS

"We shall consider only the panel-type magnetic compass. That is the kind in this aircraft and the one most commonly used. There is a lot of similarity between the turn indicator and the magnetic compass in that both instruments need interpretation in order to read them correctly. After the aircraft is under control, your next thought will be to find your heading. You must bear in mind one important rule: NEVER JUMP TO A CONCLUSION. Don't rely on only one reading of the magnetic compass. You can't look at the instrument only once and get the information you want.

"Concentrate on the turn indicator and fly the airplane straight and level, holding it as steady as you can. Once you feel you have the plane under fairly good control and think you are straight and level, then look up at the magnetic compass and make a mental note of the compass reading. Immediately return your attention to the needle and continue your efforts at holding the plane steady on a straight and level course. After some twenty seconds take another reading on the compass, make a mental note, and again return immediately to the turn indicator. In smooth air a minimum of three readings should be taken to ascertain an 'average' correct reading of the magnetic compass. In rough air you must continue to take 'readings' on the magnetic compass until such time as you have definitely determined your plane heading.

"At this point let's make a distinction. Do not think of turning until you have made a positive identification of your general direction within, say, 30 degrees. It is not particularly important to determine to the exact degree your heading. The time to strive for accuracy is when you have turned onto the reciprocal course. Now you are interested only in positively determining your general heading.

"Now you know what direction you are going. Next you must figure out what direction you want to go. This should not be too difficult. You are on a cross-country flight; you know the course that took you into the bad weather. A simple mental arithmetic problem will give you the reciprocal course that will take you back to VFR weather. The problem has now become one of turning to your reciprocal course. If on completing the steps you find that you are within fifteen to twenty degrees of your original course, which direction to turn is not important. However, if it is definitely closer to turn a certain way, say to the right, to get to the reciprocal heading, then turn in that direction. Always turn the short way around; this will avoid possible confusion, and will get the job done more quickly. Now let's consider how to use the compass in making our turn."

COMPASS TURNS

"In turning to a heading of either East or West the compass will give you a reliable indication of your actual heading, i.e., if you roll out of your turn when you see East on the magnetic compass you will actually end up fairly close to a heading of East. In making a turn to a heading of West if you roll out when you see West under the lubber line of the magnetic compass, you'll find your heading is West. In other words, when you are turning to a heading of East or West you can assume that your magnetic compass is giving you reliable information, and you can roll out as indicated.

"This is not true when turning to a heading of North. In order to end up on a heading of North you must roll out on a magnetic compass reading 30 degrees prior to North, i.e., you must 'lead' North by 30 degrees. When making a right turn to North, roll out when the magnetic compass reads 330 degrees; when making a left turn to North, roll out when the magnetic compass reads 30 degrees. Once you have started your roll out, concentrate exclusively on the turn indicator to complete the turn and to hold a straight and level course. After the compass swings back and forth a few times it will settle down on North.

"Turning to a South heading is yet another story. In this case you must go past or 'lag' South 30 degrees on the magnetic compass in order to end up on a heading of South. Example: On completion of the steps you determine your heading to be 315 degrees, or generally NW. You know that the 'good weather' is to the South, and it is your intention to turn to a South heading. What will be your reasoning in this situation? To turn from 315 degrees to 180 degrees the quickest way will involve a turn to the left. Our rule says to go past the South reading of the magnetic compass by 30 degrees. In this case we shall have to roll out of the turn when the compass reads 150 degrees. Again, once you see the 150-degree reading on the compass, roll out and concentrate on the turn indicator. Fly straight and level for at least a minute while the compass settles down. Now do the same thing that you did originally to find your heading, mentally averaging out the readings of the magnetic compass.

"We have considered the cardinal headings. What about the headings in between? Assuming a course of 045 degrees took us into instrument flight conditions, to get out we would want to fly a reciprocal course of 225 degrees, or Southwest. We know that to turn to West we roll out when we see West on the magnetic compass. To turn to South we know that we have to go past, or lag, the South reading of the compass by 30 degrees. Logically then we might expect that for half way in between the two we would split the difference, and that is exactly what is done. In the above case if we were turning around to the left we would go 15 degrees past the 225-degree compass reading before starting the roll out; we would roll out when the compass reads 210 degrees. If we had gone around to the right from 045 we would have had to roll out when the compass read 240 degrees." (Ground training is most important here. Give the student problems on figuring out his reciprocal headings and the compass readings that he should see in order to roll out on these headings. Cover the cardinal headings plus NE, SE, SW, and NW. He should know these calculations before going into the air.)

PROPER DEGREE OF BANK

"Any bank in excess of one needle width will usually give erratic readings on the compass. If the desired bank of ¾-needle width is used, then the compass will give the expected reaction.[19] If there is any error it is much better to err on the shallow side. Too steep a bank can give erroneous readings as great as 180 degrees from the actual heading of the aircraft. Avoid anything over a one-needle width turn."

MAKING SMALL CORRECTIONS OF DIRECTION

"After you have completed your turn back to 'good weather' you again must go through the process of taking readings on the magnetic

[19] If the instrument is calibrated for two needle widths as a standard rate turn, a one and one-half needle width turn should be used.

compass. Let's assume that you have determined that your present course is 20 degrees off the course you want. However, you should strive to get as close to the 'right' heading as possible. Two methods to do this are suggested. Either one or a combination of the two can be used.

"(1) *'Sneak' method.* The 'sneak' method involves using a very shallow turn to creep or edge back to the heading wanted. By doing this we are able to avoid most of the compass errors and can use the compass as a direct direction-indicating instrument. This method is especially effective in arriving at an easterly or westerly heading since there is little compass error involved in turning to these headings. The danger involved in this method is that you may not be 'sneaking' as well as you think. Perhaps you are actually making a medium-banked turn. In this case you might easily turn farther than you intended. Mental stress and unfamiliarity with compass peculiarities could well lead you into a large error. This type of error can be avoided by using the timed-turn method.

"(2) *'Timed-turn' method.* A standard rate turn in a light single-engine aircraft is considered to be a turn made at the rate of 3 degrees per second. For example, a standard rate of 3 degrees per second would mean that a 180-degree turn would take one minute; a full circle or 360 degrees would take two minutes. Now let's again consider the 20-degree correction we have to make to get exactly to our heading. Twenty degrees divided by 3 degrees per second gives us a quotient of 6 to 7 seconds; that is, if we make a 6- to 7-second ¾-needle width turn we will have turned approximately 20 degrees. With this method you will never make the large errors which can easily be made when using the compass. Turns are made with the turn indicator. Count the required number of seconds for the degree turn desired, roll out, hold the turn indicator as nearly centered as possible, let the compass settle down, and again go through the process of taking several readings on the magnetic compass to determine if you did get the amount of turn you wanted. This method may seem cumbersome at first but a little practice will show you that timed turns can be made easily. In turning to northerly or southerly headings particularly you may find timed turns less confusing than using the compass to make a small correction."

TWO DON'TS

"Two dont's which are really the same thing said two different ways are:

"(1) *Don't jump to a conclusion.* Always take several readings on the magnetic compass before you act on the direction indicated. Remember, unless you are holding the airplane straight and level, the compass is likely to give you an assortment of erratic readings.

"(2) *Don't chase the compass.* The turn indicator is the instrument that gives you attitude information. It will tell you when you are straight and level; it will tell you when you are turning. Approximately 85 per cent of your time and attention will be spent watching and reacting to information given you by the turn indicator. You will want to keep a constant check on your direction progress, but this can only be accomplished by never believing just one reading of the compass. Always read it over a period of a minute (longer in rough air) to insure that your initial reading was not taken at the extreme swing of a compass oscillation. Chasing the compass, turning immediately with every reading on the compass, can lead only to confusion. The compass gives you a check on how well you are holding your direction with the turn indicator, but be sure you have them in their proper perspective. The turn indicator is the instrument that enables you to control the attitude of the plane while on instruments. It is all important. The compass is a direction-finding instrument, and that's all it is. Used in the manner you've been told, it is an extremely reliable and important instrument. Don't try to get its information too quickly. When you have decided definitely what direction it is indicating, act on it; don't chase the compass."

LEAD OR LAG

"The number of degrees of lead or lag will roughly equal the latitude of the particular area in which you are flying. The exact number of degrees must be determined experimentally. Generally, in the midwestern region, you will find that 30 degrees is the correct amount."

FLIGHT: APPROXIMATELY 35 MINUTES

The student on entering the airplane will again briefly review the steps of the procedure. At this stage he should be doing almost all of the flying and actual manipulation of the plane. He will start, taxi, take off, and climb the plane to approximately 2000 feet. Here the instructor will take over and make a visual demonstration of the behavior of the magnetic compass. Starting on a heading of East and working around the compass, he makes a convincing demonstration. The instructor should ask the student on what reading of the compass he should start his roll out as he approaches North. Point out to the student that by rolling out on 030 degrees the plane actually ends up on a heading of North. Try to make the turns as smoothly as possible so that the demonstration will be most convincing. Complete the turn when the compass indicates it should be done. If the heading is somewhat off course tell the student why and indicate how he would make his correction. From North continue around the compass rolling out on West, South, and finally East. At each point let the student indicate on what compass reading to roll out, bringing his attention to the actual heading of the aircraft at the completion of each turn.

While on a heading of East the stage is set for a very convincing demonstration of some of the peculiarities of the magnetic compass. Declare, while on the heading of East, that it is your intention to turn to a heading of North, assuming that, like the too-large majority of private pilots, you are not familiar with the behavior of the magnetic compass. You reason that since you're on a heading of East you must make a left turn to get to North. The turn is started and the compass begins its rotation. You note that the plane is making progress towards North, but very slowly; you steepen up the turn somewhere in the vicinity of 50 degrees on the magnetic compass. The compass now actually slows down and appears to move hardly at all, so you increase the rate of turn slightly in order to "get around to North." By this time the turn is over a standard rate turn. The compass will "stick" somewhere between 60 and 30 degrees until the actual heading of the plane approaches West. As you approach West, gradually shallow out the bank and call the student's attention to the fact that the compass swings erratically and that HE NEVER SAW NORTH ON THE COMPASS. (We are using the panel-type magnetic compass.) Continue around the turn and, if necessary, make another demonstration of this startling phenomenon. Another fact with which to impress the student is that the compass momentarily reads exactly 180 degrees opposite his actual heading. Use this demonstration to re-emphasize some conclusions: (1) Don't jump to conclusions with the magnetic compass. Take enough time and several readings of the compass to determine positively what direction it is telling you. (2) Avoid any bank that is in excess of a standard rate turn. (3) Attempt to maintain a constant rate of turn. Varying the bank will make the compass oscillate, making any precision in using the compass difficult.

At the conclusion of the magnetic compass demonstration the student has all the necessary information to do the complete procedure successfully. He needs now to put all his information together and practice. In the future, emphasize the problem as a whole. Dramatize and make the simulated problems as realistic as possible. The student may need more practice in doing the steps necessary to get control of the aircraft. If so, be sure he masters them before continuing. He is then ready to do the "whole" routine. Something along these lines is suggested.

"Let's assume we're on a cross-country flight to East St. Louis. We're cruising along at 2000 feet. The weather doesn't look too good, but we feel sure that we can make it there before the front moves into the area. Our course is 225 degrees. We're just starting to let down a bit in order to get underneath the clouds when, WHAMBO, we're in it. OK, you've got it." (As the instructor says this, the student should have the goggles on to get used to the restricted light in the cockpit as seen through the blue goggles.)

Now the student has the entire problem of control, direction, turn, and let-down. At first he may need some assistance, such as reminders to watch the turn indicator, shallow out the bank, etc. As the student progresses, every attempt should be made to make him as self-sufficient as possible. After he has gained some proficiency the only information that he ought to need from the instructor is (1) the problem: where he is going, the circumstances of the flight, and the fact that he just ran into instrument-flight conditions, (2) any weather information needed to indicate a possible let-down, and (3) the end of the problem.

To inform the student of his progress and make the instruction easier, show the student where he is starting the problem, i.e., give him his geographical location and let him see it before he starts the problem. When he has completed the turn and made his way approximately five miles back beyond his starting point, it is logical to assume that he has returned to the "good" weather. When he is told to lift his goggles call his attention to the relation between his present position and his starting position.

It is not necessary to incorporate a let-down into every practice run through the steps. However, it is practical to have the student make a let-down on the practice run immediately prior to the return to the airport. The instructions should have enough variety so that the student is thinking for himself but still performing the steps as routinely and mechanically as possible.

Time will probably not allow more than two or three practice trials of the system during period 3.

Periods 4 and 5

Purpose: To attain proficiency in the procedure. Since the mechanics of the system should take little time to perfect, the majority of time will be spent practicing the technique of controlling the turn indicator with the rudders, along with practicing the proper use of the magnetic compass.

PREFLIGHT DISCUSSION: APPROXIMATELY 5 MINUTES

At the end of period number 3 the student has all the necessary information to do the procedure successfully. From here on it is constant practice. The discussion will take the form of review. Generally, unless there are specific problems, only a short review is necessary before flights four and five. However, if there are problems the time to correct them is on the ground. On the fourth flight it is essential that the student understand clearly the behavior of the magnetic compass, and he should be given several problems on the ground to make sure of this. Cover any difficulties encountered in the second and third flights to avoid a repetition of them. Take as long as necessary to make certain all points of the procedure are clear before starting the flight.

FLIGHT: APPROXIMATELY 48 MINUTES

Normally, practice will consist of problems of a similar nature to the cross-country problem given in period 3. Assuming no difficulties, the student should be able to do about five of these in the allotted time, each taking from 4 to 12 minutes, averaging probably around 7 minutes. If any part of the procedure presents difficulty, take care of it immediately.

At some time during the fourth or fifth flight, the instructor should permit the student to make a let-down to an altitude of 50 to 100 feet. This is to show him that in an extreme emergency he could make a controlled let-down under the most adverse ceilings and visibilities. It should be pointed out that this requires a calculated risk involving TV towers, etc., but even if the airplane crashes, if at the time of contact it was in a gradual descent, the chances of the occupants living are better than they would have been with no control.

At least once during the fourth flight the instructor should let the student do a complete problem without any "coaching." This serves a dual purpose: It gives both the student and the instructor an appraisal of the student's progress and forces the student to think for himself. Do this at least twice on the fifth flight. The instructor will make a notation of any mistakes or aids that he can offer to the student on the completion of the problem.

Period 6

Purpose: (1) To test the student's ability to do the self-saving procedure. (2) To allow the student to test any innovations of his own invention. (3) To emphasize the "get out" rather than the "get through" aspect of the procedure.

PREFLIGHT DISCUSSION: APPROXIMATELY 5 MINUTES

"This is the last period of the curriculum. It will be a flight test consisting of three separate problems similar to the ones we have been practicing. The first problem will be a cross-country flight to Memphis. When we are well clear of the airport and at cruising altitude we'll encounter 'instruments.' The problem is yours alone. The only information you'll be given is when to start, weather information to help you to decide whether and how far to let down, and when you are through with the problem. You'll get a look at the point where you start the problem before you put on the goggles so that you will be able to realize your progress after removing the goggles at the conclusion of the problem. The other two simulated instrument problems will be similar and you'll get the necessary information for them in the air."

FLIGHT: APPROXIMATELY 42 MINUTES

It is the instructor's duty to be sure that the student is absolutely clear on his part in the test. During the process of teaching, the student sometimes becomes dependent on the instructor for cues and help. Any tendency toward this should be completely dispelled before giving the student the final problems. Give him the problem, show him his geographical starting point, and start the simulated instrument encounter. If you want him to make a let-down, then give him the weather information that would lead to that logical conclusion.[20] After he has successfully completed his turn and is back approximately 3 to 5 miles beyond his starting

[20] This is to simulate the type of situation where he could listen to a weather sequence on the radio or communicate with a CAA Communications station.

point, have the student lift his goggles and observe his location. Leave the student "on instruments" until he either breaks out of the "weather," gets into a dangerous flight attitude, or spends too long trying to get back. The instructor should give no coaching. He should make the experience as realistic as possible.

After successfully completing the 180-degree procedure three times, the student should be given the opportunity to have another simulated instrument encounter during which he has a "free rein," that is, explain to him that the curriculum is over but that he can have one more try at a simulated instrument flight. He must still do his best to get out of the bad weather, but he can use any means he wishes to do so. He can use the 180-degree procedure, modify it if he desires, or use a method of his own.

The purpose of the "free rein" instrument try is to convince the student that the practiced procedure is better than an impromptu and improvised system of his own. The student may have enough confidence in the self-saving system so that he will not want to try anything else; he knows that the 180-degree turn procedure will work. However, he may want to help the oscillations along by controlling the elevators. In that case, sooner or later, the student will give just the opposite stick pressure needed and actually aggravate the oscillations.

The student must understand that the 180-degree turn system is a procedure to use only in case of emergency and in order to get out of the instrument flight conditions. This point can be brought vividly to the student's attention by asking him to fly, under simulated instrument conditions, to a certain airport. He must have the same equipment that a qualified pilot would need to get there on instruments. For example, at the University of Illinois the student might be requested to take the instructor to Chanute Air Force Base. The essentials are there: RAN — a low-frequency radio range station, a low-frequency receiver in the plane, and of course the primary instruments necessary for instrument flight.

What the instructor asks the student to do will depend on the equipment in the plane. If the plane is equipped with Omni or ADF he might ask the student to take him to the nearest airport with navigational facilities. The whole point is to prove to the student that the 180-degree procedure can get him out of trouble but that it is not sufficient to get him through to a destination by instrument flight. The student at the completion of the course should be sufficiently impressed with the problems of instrument flight that he will avoid instrument flight conditions until properly trained.

POSTFLIGHT DISCUSSION: APPROXIMATELY 13 MINUTES

"There are several factors concerning the 180-degree course that should be called to your attention now that you have completed the curriculum. While you have demonstrated your proficiency in doing the procedure today, there is some doubt that you will still be able to do it six months from now. In order to keep an instrument rating current a pilot must practice six hours every six months, or an average of one hour a month. Practice this system occasionally. You could do this on a cross-country flight with little sacrifice of time. However, in order to remain proficient on the 180-degree procedure it is essential that some kind of an instrument flight simulating setup be used in your airplane. It has been proved that even the slightest cue outside of the aircraft is enough to enable the pilot to control the attitude of the plane.

"The problem of the transition from VFR to instrument flight was clearly defined for us during the course. That is, you had no trouble in making the decision to use the emergency 180-degree procedure. Once you lowered the goggles you couldn't see anything outside. Also, you were mentally prepared for an instrument flight; you knew that you were going to practice the procedure when you got into the airplane. This is not true for the emergency when you inadvertently find yourself 'on instruments'. If you had any inkling that your flight was going to encounter instrument flight conditions you wouldn't have taken off in the first place. When to stop trying to see the ground and admit that you no longer have outside references by which to control the attitude of the aircraft is a very real problem. Even qualified instrument pilots have been known to get into trouble by not making a timely transition from contact to instrument flight. Occasional glimpses of the ground are not enough to maintain successful contact flight. As soon as there is any doubt about whether you can successfully continue your flight on visual flight rules you should turn back, land, or make some decision that will keep you out of trouble. If you do find yourself in instrument flight conditions, then act immediately. Go through the self-saving procedure. Hesitating, flying half contact and half instruments, is extremely dangerous.

"Panic is a situation that is impossible to simulate. You know that an instructor isn't going to let you get into any attitude or flight condition from which he can't recover. Panic in this case isn't a factor. But it can be a very real factor should you find yourself in an actual situation where you have to control the aircraft solely by reference to instruments. Having in mind a positive course of action such as the self-saving system is a definite deterrent to panic. Practicing it until it becomes automatic, and reviewing it often, may sometime save your life."

Appendix

WEIGHT AND BALANCE FOR THE BONANZA USED IN THIS EXPERIMENT

Critical Rearward CG Check (Full Fuel)

ITEM	WEIGHT	ARM	+ MOMENTS
*Aircraft W.E.	1711.3	+ 77.8	133275.8
Front Seat	340.0	+ 85.0	28900.0
Oil (2½ gal.)	18.7	+ 35.0	656.25
Rear Seat	340.0	+116.0	39440.0
Fuel (40 gal.)	240.0	+ 75.0	18000.0
Baggage	50.0	+139.0	6950.0
Totals	**2700.0**		**227222.05**

$$\text{Rearward CG} = \frac{227222.05}{2700} = 84.16\text{" Aft of datum}$$

Rearward CG at 2700 lbs. is (+84.4)

* Includes unuseable fuel 6 lbs. at (+79) and unuseable oil 3 lbs. at (+37).

FOR WEIGHT AND BALANCE AND CG RANGE SEE CAA SPECIFICATION A777 Rev. 22.

Critical Rearward CG after 1⅓ hrs. Flight with 13.33 gal. of Fuel Consumed

ITEM	WEIGHT	ARM	+ MOMENTS
*Aircraft W.E.	1711.3	+ 77.8	133275.8
Front Seat	340.0	+ 85.0	28900.0
Oil (2½ gal.)	18.7	+ 35.0	656.25
Rear Seat	340.0	+116.0	39440.0
Fuel (26⅔ gal.)	160.0	+ 75.0	12000.0
Baggage	50.0	+139.0	6950.0
Totals	**2620.0**		**221222.05**

$$\text{Rearward CG} = \frac{221222.05}{2620} = 84.43\text{" Aft of datum}$$

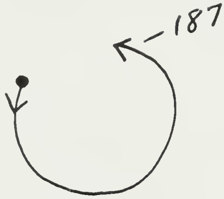
Rearward CG limit at 2620 lbs. is (+84.4)

* Includes unuseable fuel 6 lbs. at (+79) and unuseable oil 3 lbs. at (+37).

FOR WEIGHT AND BALANCE AND CG RANGE SEE CAA SPECIFICATION A777 Rev. 22.

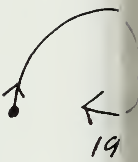
Representative Case Records

Start 1534
Stop 153604
Altitude −600
Low AS Cr
High AS 187
Bank +50



Remarks: Graveyard spiral left

Start 1537
Stop 154000
Altitude −800
Low AS —
High AS 190
Bank +50



Remarks: Graveyard righ

Start 1543
Stop 1548
Altitude OK
Low AS 120
High AS 165
Bank +50

Lost directional orientation completely

Remarks: Turn slowed due to sun visible thru glass?

Start
Stop
Altitude
Low AS
High AS
Bank

Remarks:

Subject # 13
Date: 3-18-54
Period # 1

Take Off 1521
Land 1553
Total Flight 32

Total Discussion 35
Total S.I. 10

a	Start
o	Stop
tide	Altitude
w AS	Low AS
g AS	High AS
n	Bank
visual demonstration of steps	3 visual attempts by Subject
m ks:	Remarks: Slow on steps

rt 1714	Start
p 1732	Stop
itle	Altitude
v S	Low AS
gh AS	High AS
k	Bank
times thru steps S. I. plus practice trolling needle th rudder.	Emphasize necessity for constant check on needle and appropriate correction
ks: Pauses between steps	Remarks:

ject #: 13
e: 3-19-54
o #: 2

Take Off 1655
Land 1737
Total Flight 42

Total Discussion 40
Total S.I. 18

Start
Stop
Altitude
Low AS
High AS
Bank

1 S.I. demonstration of steps

Remarks:

Start 1537
Stop 1555
Altitude
Low AS
High AS
Bank

3 S.I. attempts by subject

Remarks: Rough air. Wind 40+

Start
Stop
Altitude
Low AS
High AS
Bank

Remarks:

Start
Stop
Altitude
Low AS
High AS
Bank

Emphasize necessi[ty] for constant ra[te] of turn

Remarks:

Subject # 13
Date: 3-25-54
Period # 3

Take Off 1523
Land 1603
Total Flight 42

Total Discussion 35
Total S.I. 18

d 1630

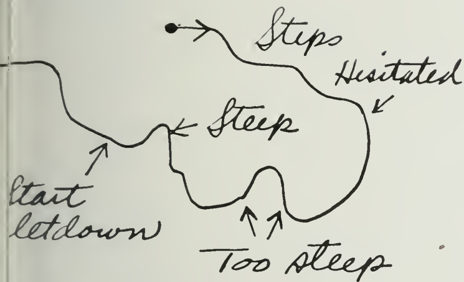
d 1643

itude -300

AS 80

g AS 150

r OK



rks: Hesitated too long

figuring reciprocal

Start 1645

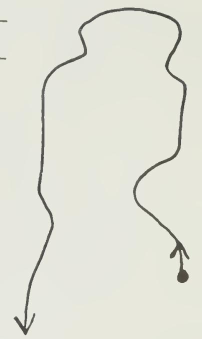
Stop 1656

Altitude +100

Low AS 76

High AS 145

Bank OK



Remarks: Erratic Turn and

needs to watch needle more

while going thru first

5 steps.

t

p

tle

S

AS

k

Reemphasize constant

te of turn and that

e needle is absolute

axemum.

s:

Start

Stop

Altitude

Low AS

High AS

Bank

Remarks:

e # 13

: 3-25-54

4

Take Off 1625

Land 1701

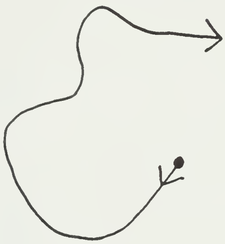
Total Flight 36

Total Discussion 25

Total S.I. 24

Start 1054
Stop 1102
Altitude +50
Low AS 80
High AS 140
Bank OK

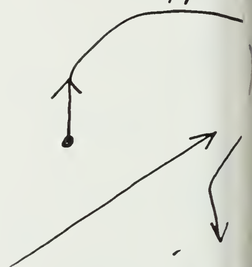
Bank too sharp



Remarks: Steps much better

Start 1104
Stop 1112
Altitude +100
Low AS 70
High AS 140
Bank OK

Stopped



Remarks: Gave WX inform
let down OK.

Start 1113
Stop 1118
Altitude -200
Low AS 76
High AS 140
Bank +

no good

Too steep

Did not concentrate on needle while doing first 5

Remarks: steps. Demonstrated steps from unusual attitude.

Start 1123
Stop 1132
Altitude +100
Low AS 80
High AS 140
Bank OK

Remarks: Good timing on steps.

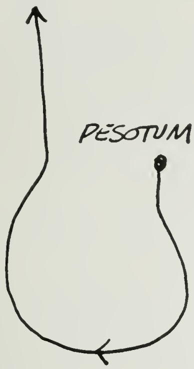
Subject # 13
Date: 3-28-54
Period # 5

Take Off 1050
Land 1136
Total Flight 46

Total Discussion 20
Total S.I. 30

a 1511
p 1518
ide +100
AS 86
g AS OK
n OK

Destination
MEM



ks: Excellent

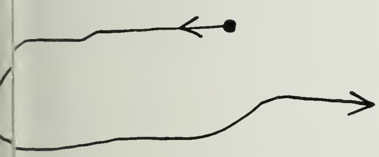
Start 1520
Stop 1526
Altitude Same
Low AS 80
High AS OK
Bank OK

Destination
STL

Remarks: Very good. 30-45 sec. to do steps 1-5

t. 1527
p. 1534
tue OK
s 80
h S OK
k. OK

Climbing toward SPI



a: Trim ½° off.
ery good

Start 1536
Stop 1542
Altitude OK
Low AS 85
High AS OK
Bank OK

Free trial. No variation in steps.

Remarks: Test OK. Average to above average subject

e # 13
: 4-4-54
d # 6

Take Off 1505
Land 1547
Total Flight 42

Total Discussion 20
Total S.I. 26

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